Exotic and invasive terrestrial and freshwater animal species in the Dutch Caribbean

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Summary

We here provide an overview of 72 invasive animals of the terrestrial and freshwater environments of the Dutch Caribbean, eleven of which are no longer present. All invasive animals that are principally agricultural pests and or animal and plant diseases (46 species) are excluded as these are discussed separately elsewhere. The 61 species documented and discussed here as presently living in the wild or semi-wild state on one or more of the Dutch Caribbean islands, amount to 12 exotic mammals, 16 birds, 13 reptiles, 5 amphibians, 2 freshwater fishes, 3 insects, 2 mollusks and 8 exotic earthworms. For most species, the ecology, distribution, status and current impact remains poorly known as few invasive species have been object of directed studies.

Some of the most deleterious animal introductions have been mammals, particularly the grazers and the predators, most of which have been introduced in the historical past. Among these, the four key species are grazing goats, the mongoose the cat and the black rat. In most cases, such species cannot be eradicated because they are widespread and firmly established or even kept as livestock. Nevertheless, these species must urgently be controlled in sensitive areas where possible. Our review also shows that many introduced mammals and reptiles are still present in relatively small populations, making eradication still very feasible.

Seven species have the status of being native in parts of the Dutch Caribbean but introduced to other parts where they are not native. The most threatening of this last category is the green iguana, as introduced to St. Maarten where it outcompetes and hybridizes with the weaker Lesser Antillean iguana.

The key priorities for successful action against invasive exotic animals are:

- the control of goats;
- control of introduced predators (rats and cats) near seabird breeding colonies;
- eradication of several small populations of exotic mammal predators and reptiles as long as this is possible before the get a strong foothold and spread;
- eradication of introduced species from small satellite islands which serve (or served) as seabird breeding habitat.

In addition to such on-island action against species already present, it is critical to prevent further introductions. The most important pathways to focus control on are the container transport of goods, the international trade in pets and the trade in ornamental plants.

Two key action points are urgently needed: a) develop the existing legislation and b) invasive species management teams (ISMTs) empowered for action. It is essential that these initiatives be firmly imbedded in a policy framework. The first step ahead in these respects should be to outline an Invasive Species Strategy and Action Plan (ISSAP). However, in the interim, the lack of an ISSAP should not hinder directed critical action at the local level (eg. against goats in the national parks and cats at seabird breeding sites).

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1 Introduction

Non-native species are being transported across the globe at alarming rates due to the globalization of economies, the rapid growth in the use of containerized transport (Reiter 2010) and the ease of rapid human air transport on massive scales. When exotic animals establish themselves in a new environment, they interact with the native flora and fauna in several ways. They may act as predators, competitors, disturbing agents, carriers of disease or even hybridize with native species and threaten unique and adapted gene pools. Some of such species will also become invasive and can impact endangered species or have extensive ecosystem impacts, which may include effects on vegetation, ecosystem dynamics, and ecosystem resilience. Lugo (2009) points to the role of invasive (plants) in creating novel forests that show little resemblance to original forest prior to deforestation. Such species can have major impacts on agriculture, ecosystems, endangered species, and even human health and well-being.

After habitat destruction, invasive species represent the single greatest threat to global biodiversity and are a costly burden to agriculture worldwide (Kaiser 1999, Mooney 2001, Powell et al. 2005). In the USA annual costs caused by invasive species are estimated at 120-137 billion (Pimentel *et al.* 2005). Aside from human-mediated transport being their principal vehicle for introduction, the establishment of exotic invasive species are also generally helped-along by disturbance caused by man and his varied land-use practices, or even by man-induced climatic change. Landscape-impacts create special habitats that such species can invade but they also reduce the ability of native species to compete with, resist and expel foreign intruders.

As pointed out by Moutou and Pastoret (2010) the definitions used to define invasive alien species depend on the view-point assumed for the research. In the invasive aliens species literature a large number of terms are in use, among which exotic, alien, introduced, tramp, cryptogenic, anthropochorous, watch list, alert list, red list white list and black list. To complicate the matter, these terms may be used to describe species spread both by man (intentionally or inadvertently) or also by natural means.

2 Objectives

In the Dutch Caribbean, invasive species have received sporadic attention but no formal publications exist that provide a broader overview of the occurrence and distribution of the species concerned. Based on a preliminary overview by Esteban (2006) it was quite evident that the problem must be large. The topic of invasive species has been identified as a critically important issue for nature conservation in the Dutch Caribbean since the drafting of the first nature policy plan 2001-2005, and remains so today (Debrot *et al.* 2011).

In light of the fact that invasive alien species (IAS) remain an urgent concern, the Dutch Ministry of Economic Affairs, Agriculture and Innovation commissioned IMARES to provide an update and overview of invasive species for the Caribbean Netherlands and recommend key actions. In this overview we specifically address the exotic and invasive animals species of the terrestrial and fresh water environments of the Dutch Caribbean, that are not primarily agricultural pests and diseases. Those species are reviewed in a separate report, as are marine exotic species and exotic terrestrial plants. While the focus of this report is the Caribbean Netherlands (Bonaire, Saba, St. Eustatius), the need to include the other three island territories of the Dutch Caribbean (Aruba, Curaçao and St. Maarten) in our overview was dictated by:

- General interconnectedness of the Dutch Caribbean islands in terms of short geographical distances for mobile species
- A centuries-long common history of exposure to exotic species and actual introductions
- The intensive and enduring economic ties and material and human traffic between the islands
- The fact that the IAS problem is truly a shared problem, with a high degree of overlap in species and issues.
- The fact that IAS are often costly to combat, optimally calling for a joint and coordinated approach based on a shared awareness.

As we here also use four key terms to classify and grade the species in terms of the extent to which they are invasive, we here have to clarify those terms. We use the term “exotic” to refer to species that originate from “elsewhere” and that are relatively “recent” arrivals to the islands. “Exotic” species which have so far been limited to captivity (e.g. hamsters), or which never had reproductive potential (e.g. caymans found at Muizenberg in Curaçao) are not included. Also possible prehistoric and pre-colonial introductions by “native” man are not discussed here. Exotic species that are present in sufficient numbers to reproduce and multiply, and hence have the minimum potential needed to persist without directed assistance by man are here referred to as “established”. Those established species that have survived, reproduced and spread, such that they have integrated and persist into natural or semi natural communities are referred to as “naturalized”. Finally, naturalized species that have also spread such that they have proven or presumed substantial negative impacts on ecosystems or other species are referred to as “invasive”. Invasive species typically develop themselves through these various stages before exhibiting the full scale of problems they may represent. Other species never make it through all stages.

In this report we provide an overview of the species concerned, their current status, on the islands, and as far as could be found, their region of origin, approximate period of introduction, and prospects and priorities for research and eradication or control. An overview of the principal results is presented in Appendix 1.

3 Species Accounts

3.1 Mammals

3.1.1 Rodents

House mouse, *Mus musculus*

The house mouse is usually found in and around houses. In Curaçao they can sometimes be found in large numbers in sorghum fields. The species originates in Eurasia. The data by Bekker (1996) strongly suggest that the original native Aruba Vesper mouse *Calomys hummelincki* has been displaced by *Rattus rattus or Mus musculus*, but that the Vesper mouse can maintain itself on the sparsely vegetated northern coastal plateau where the anthropochorus rodents are rare. Here sparse grasses dominate. The Vesper mouse is also found in Curaçao and in the Northern parts of South America. In Curaçao it is very rare (Debrot *et al.* 2001) and likely strongly declined in abundance and distribution. This can probably be partly explained by the fact that the northern coastal plateau in Curaçao receives somewhat more rain and has somewhat more vegetation than in Aruba. This could work to the advantage of *Rattus rattus* and *Mus musculus.* The mouse is an economically costly invasive species. It costs a lot to control and causes untold damage to crops, and foodstuffs in the domestic environment.

Brown rat, *Rattus norvegicus*

The Brown rat is thought to have originated in Northern China. It is found in an urban environment. Other names are Norwegian rat orSewer rat. On these islands it is mostly found in parts of town with decrepit sewage systems and in the harbor areas (Husson 1960).

Black rat, *Rattus rattus*

The Black rat is thought to originate in South-East Asia. On the Caribbean islands these rats are never black (Husson 1960) but range in color from dark to light brown and can have various shades of grey. They can also have a beige color. The underside varies from clear white to dark grey. This rat is the most common rat on the islands. It can also be found in the field, away from houses. Often black rats construct nests in trees, which resemble birds' nests. Such nests are quite commonly found in the red mangrove (*Rhizophora mangle*). Husson (1960), states that the practice of nesting in trees has given *Rattus rattus* some defense against mongoose on islands where the mongoose is present and that this probably explains why the mongoose has never succeeded in exterminating the rat population on any such island. In Aruba it was found that the black rat constitutes an important food item for the introduced *Boa constrictor* (Quick *et al*. 2005). The only existing study on these islands that quantifies the distribution of rats and mice is the work by Bekker (1996) on Aruba. Bekker did trapping studies and collected road kills. He found *Rattus rattus* all over Aruba but in higher numbers near human population centers.

Inevitably the Old World rats and mice that came in after 1499 (belonging to the family of the Muridae), displaced the native New World rats and mice (belonging to the family Cricetidae). The black rat played the major role. The Cricetine *Oryzomys gorgasi* may have survived in Curaçao till colonial times and was probably displaced by the black rat (McFarlane and Debrot 2001 and Voss and Weksler 2009). Rats are a key problem for ground-nesting seabirds in both Saba and St. Eustatius (Collier and Brown 2008a, b). The species costs a lot to control and causes damage to crops, and foodstuffs in the domestic environment. Eradication is impossible but local control can be effective and is highly needed particularly in certain bird nesting areas. It is the most wide-spread and common mammal on St. Eustatius (R. Hensen, pers. comm.).

3.1.2 Household pets

Dog, *Canis familiaris*

The dog was widely present in the Caribbean during the pre-Colonial period (Masseti 2001), and could also well have been present in small numbers on the islands centuries before discovery and settlement by Europeans. Nevertheless, today, the dogs present on the islands are numerous and fully derived from imported races. As active and roaming predators they form an important threat particularly to larger fauna (such as deer on Curaçao, cottontails on Curaçao and Aruba, and iguanas and declining land crab populations on all islands. Roaming dogs are also an important disturbance to ground-nesting seabird colonies (Debrot *et al.* 2009).

Cat, *Felix domesticus*

In Aruba, Curaçao and Bonaire feral cats are generally associated with man but can survive in the wild on their own. They can be found at sites far from human habitation such as the eastern end of Curaçao, Klein Bonaire and the 60 km^2 Washington Slagbaai Park on Bonaire (AOD, pers. obs.). Cats have been introduced to uninhabited islands elsewhere in the world and can have major impact on endangered species. However, most cats impacting nature live in close association with man. It is not known, what the effects of their predation is. On an island like St. Eustatius where there is a small population of the endangered *Iguana delicatissima*, predation by stray cats could be of significance. One can also imagine that the presence of stray cats could influence populations of the ground lizards *Ameiva erythrocephala* (St. Eustatius) and of *Ameiva pleei* on St. Maarten. In Saba stray cats are a serious problem for the rare tropicbirds *Phaeton aethereus* and *Phaeton lepturus*, which nest on steep cliffs (Collier and Brown 2009). Eradication with the nematocide Temic-10 (“tres pasitos”) sorted good results both in Saba and on Klein Curaçao (AOD, pers. obs.). However the eradication of cats on Klein Curaçao has been followed by an apparent increase in the number of rats (G van Buurt, pers.obs). On Saba a cat sterilization program has been tried (Collier and Brown 2009). Cats are a key problem for ground-nesting seabirds in both Saba and St. Eustatius (Collier and Brown 2008a,b). Eradication is impossible but local control is feasible and urgently needed near sensitive bird nesting areas. Algar *et al.* (2003) discuss a range of methods used for successful eradication and control of cats in the Pacific islands.

3.1.3 Livestock

Goat, *Capra hircus*

Goats were introduced to the Dutch Caribbean early in colonial times and today still are the principal livestock species held on the islands. The goat grazing problem has been known to be an issue for a long time (Coblentz 1980, Brink 1998, Debrot and Sybesma 2000, Freitas *et al.* 2005). It is easier to address in the areas owned by national park organizations than on public lands. It has effectively been addressed on Curaçao in the Christoffel park as well as on the islands of Klein Curaçao and Klein Bonaire (Campbell and Donlan 2005).

In Curaçao, nowadays goats and sheep which roam around in the bush are likely to be stolen. Consequently, there are only few animals out in the bush and grazing pressure is much less than it used to be. Thus extended dry periods do not affect the vegetation to the same extent as in the past. In the past the thorns of the opuntias were burned off with flamethrowers, thus enabling the goats to eat them. Often the burning would cause brushfires. Nowadays opuntias are not being burned anymore as imported food is available. Debrot and de Freitas (1993) described patches of livestock-inaccessible rock vegetation in Curaçao and compared these to similar rock surfaces which had experienced livestock grazing. Grazed and ungrazed rock vegetation were totally different in diversity and species composition. Grazed rocks had principally cacti and *Acacia* whereas ungrazed rocks were characterized by high densities of bromeliads and orchids. Since 1993, goats have been structurally caught and removed from the Christoffelpark in Curaçao thereby reducing densities rapidly to about 0.1 goat per hectare (C Schmitz, pers. comm.). Methods used included various forms of trapping and systematic shooting. The

success has been large and dramatic with large-scale improvement in vegetation densities and recovery of rare plants. Goat control in Curaçao and recent results with goat exclosures on Bonaire show that rapid vegetation recovery is feasible. In the Washington Slagbaai National Park of Bonaire, counts in 2009 indicate some 6000 goats in the park, amounting to about 1 animal per hectare (AOD, unpubl. data). The availability of suitable forage is so low that the animals now resort to gnawing the bark off the large, old candelabra cacti thereby killing these key suppliers of flowers and fruits for other fauna such as birds and bats.

The best prospects for addressing the overgrazing issue in the Caribbean Netherlands are inside the Washington Slagbaai Park in the section of Slagbaai, which is privately owned and where the park management has full authority to deal with the problem. Preparations have been made for eradication by separating Slagbaai from the Washington section with a perimeter fence to prevent goat movement, and experienced volunteers to guide this effort have been identified. A recent review by Staatsbosbeheer stresses the urgent need to address this issue for the park (Blok 2010).

Figure 1. Goats and donkeys inside the Washington Slagbaai National Park are decimating the population of adult candelabra cacti by gnawing off the bark of these important trees. The trees form a key food source for other animals such as birds and bats (Photo: AOD 2009).

Control of goats is a top priority on all islands (Debrot *et al.* 2011). However in general the park organizations have been poorly equipped to deal with the grazing issue.

Besides the major impacts from grazing there are also generally minor impacts from livestock trampling. In Aruba for instance some rattlesnakes are trampled and killed by hoofed animals such as goats, sheep and donkeys. The rattlesnake does not run away when threatened, but stays coiled and gives warning with its rattle. In any case, strange as it may seem, the protection afforded by the rattle is not always effective and it has been established that in Aruba some rattlesnake snakes do get trampled and killed (Reinert *et al.* 1995, 2002). In Addition, trampling by goats are a recognized and serious problem for endangered seabirds in Saba and St. Eustatius (Collier and Brown 2008a, b). On St. Eustatius, goats cause landslides in the Quill crater and Lower-Town cliffs and are a threat to vegetation (esp. terrestrial orchids) in Northern hills (R. Hensen, pers. comm.). According to STENAPA the livestock on Statia at present amounts to approximately 1500 head of cattle, 2000 goats, 1000 sheep, 150 donkeys and 200 swine, of which 10-15% are kept fenced in (Jongman *et al.* 2010).

Donkey, *Equus asinus*

The donkey is an important problem in the Leeward islands, particularly Bonaire. A public/private plan to sterilize the donkeys and keep them in a compound has failed to solve the serious ecological and safety problem they represent. They are a formidable grazer, cause erosion and also cause damage to gardens. They are responsible for many traffic accidents annually on Bonaire. Donkeys used to be a farm animal and are good to eat, just as are horses. Control of donkey numbers is essential. They appear to be a specific threat to the endangered Sabal palm on Bonaire (R. Hensen, pers. comm.).

Horse, *Equus equus*

The feral horses of Bolivia on Bonaire used to be an export product of the island (Husson 1960). These have all been removed. Feral horses are no longer an ecological issue in the Dutch Caribbean.

Sheep, *Ovis aries*

Sheep were also introduced to the islands during the early colonial period. They continue to survive in both tended and feral populations. They are much less adapted to living in the wild than goats and are much less numerous. The effects on the vegetation is similar to that of goats. The main difference is that sheep principally seek out flat lowlands while goats show a strong preference for higher terrain.

Feral pigs, *Sus scrofa*

The Aruba, Curaçao and Bonaire Creole pigs probably derive from Iberian stock. Christopher Columbus brought eight pigs with him in 1493 when he crossed the Atlantic from Portugal. His ships had taken supplies, including pigs and livestock, in the Canary Islands (Gomera). Released on the West-Indian islands, they soon became feral and, with various others dropped off here and there by various navigators and explorers from Portugal and Spain, they rapidly populated the Spanish Indies, spreading in due course to mainland America (Parker, 1993). The Curaçao Creole pig is a black haired pig, while the Aruba Creole pig is usually blotched, although some Curaçao pigs are also blotched. In Bonaire both black and blotched pigs are found. The Aruba pig is probably derived from a small population of Curaçao pigs. The tails are straight; there are no curls in the tail. The skull slopes gradually, almost without the bend found in the Holland landrace. The head is relatively large. In later years these Creole pigs have been mixed with Yorkshire, Duroc and most recently Holland landrace. It is now difficult to find Curaçao pigs which seem pure. There is no program to preserve these pigs. In the past many of such pigs used to roam around in the bush and had an effect on nature. Pigs are a notorious conservation problem on islands world-wide (Cruz *et al.* 2005; Nogueira-Filho *et al.* 2009, Hilton and Cuthbert 2010), including various Caribbean islands. The problem of feral pigs on Curaçao at present is less than it used to be. At present feral pigs are a serious problem in the Washington Slagbaai National Park of Bonaire, where they

extensively uproot former aloe fields in search of invertebrates. In Curaçao, feral pigs are of growing concern on the mid- to western side of the island, now that they are no longer being hunted. They are also a problem on St. Eustatius (R. Hensen, pers. comm.).

3.1.4 Other Mammals

Capuchin monkey, *Cebus* sp.
A group of capuchin monkeys was observed for a number of years in the higher reaches of the Christoffel Park in Curaçao, and even photographically documented (AOD, pers. obs.). The monkeys have since disappeared. One individual was found dead at a dry waterhole. The monkeys probably died due to one of the droughts.

African civet, *Civettictis civetta*
The African civet (*Civettictis civetta*) which was introduced in Curaçao from West-Africa in the 17th century by the Dutch West-Indian Company (WIC) in order to produce civet, a type of musk. Some animals escaped and feral populations existed up to the 18th century (Husson 1960). Eventually however these feral populations did not survive.

Vervet Monkey, *Clorocebus pygerythrus*
This monkey is present on St Maarten (Esteban 2009). Th especies is present on various islands in the Caribbean and on St. Kitts it is regarded as responsable for the extinction of an island endemic, the St. Kitts bullfinch. On St. Martin, Brown and Collier (2006) consider it responsible for declines in dove and thrasher populations. The population is still small and trapping should easily be able to eradicate the species before population numbers grow out of hand (Brown 2008). The species has been reported for St. Eustatius in the past (Masetti 2011), but it apparently is no longer present (R. Hensen, pers. comm.). On St. Kitts these animals represent an infectious invasive disease risk to humans (Whitehead *et al.* 2010).

Mongoose, *Herpestes auropunctatus*
The mongoose is established on St. Maarten. (Nellis and Everard 1983, Brown 2008). It is responsible for the extinction of a large number of reptiles and birds throughout the Caribbean (Nellis and Everard 1983, Westermann 1953). In St. Maarten it was introduced in 1888 to provide rodent control, especially in sugar fields. On some other islands it was imported in order to control fer-de-lance (*Bothrops*) snakes as well. Once established it became a threat to several species of birds and ground lizards and species of harmless snakes as well. It has been documented to kill birds, reptiles and land crabs on St. Maarten (Brown 2008). It is well spread across habitats on the island and shows little habitat dependencies. Densities can be high with an average of 22 animals per hectare (Brown 2008). Eradication is unlikely and the priority is to prevent its spread to neighboring islands and offshore seabird nesting rookeries, such as Tintamarre (Brown 2008).

Raccoon, *Procyon lotor*
The raccoon is present on St. Maarten. It is currently culled through trapping and hunting. Three species of related raccoons have been introduced into the Caribbean but while it indeed was unclear which form is present on St. Maarten (Brown 2008), the question has been settled (Helgen *et al.* 2008). The current population is estimated at 20-30 animals, which makes eradication fully feasible.

3.2 Birds

Orange-winged parrot, *Amazona amazonica*
In Curaçao feral populations exist that originated from escaped cage birds (Prins *et al.* 2009).

Red-lored parrot, *Amazona autumnalis*
This species has been recorded nesting in the wild in Curaçao (Prins *et al.* 2009). The species has not been recorded for many years and probably has not established itself.

Yellow-crowned parrot, *Amazona ochrocephala*
In Curaçao feral populations exist that originated from escaped cage birds (Prins *et al.* 2009).

Chestnut fronted ara, *Ara severa*
A feral population is now found on Curaçao (Prins *et al.* 2009) and they nest successfully in church steeples (S. Ignacio, per. comm.). Their survival seems to depend on gardens.

Blue crowned Parakeet, *Aratinga acuticaudata*
In Curaçao feral populations exist that probably originated from escaped cage birds. This bird is also found in dry areas in Venezuela such as for example in nearby Paraguaná. This species may be able to spread out in the future; their survival might not depend exclusively on gardens. Again very little is known about this. It has been observed to eat the fruits of an invasive tree *Ziziphus spina-christi* (GvB, per. obs.)

Cattle egret, *Bubulcus ibis*
This species was first recorded for Aruba in 1944 (Prins *et al.* 2009). It is possible that the species came over from Africa on its own accord and was able to establish itself especially due to the agrarian and urban environment provided by man. Today is the most abundant egret on the islands of Aruba, Curaçao and even St. Eustatius (R. Hensen, pers. comm.). It might compete with other species for rare roosting and nesting sites. On Bonaire it still is only an occasional visitor (Prins *et al.* 2009), but may be increasing in numbers (F. Simal, pers. comm.).

Rock dove, *Columba livia*
This species is introduced worldwide. In Curaçao it is established in several natural areas, such as Hato, Boka St Michiel and Roi Rincon (Prins *et al.* 2009). The bird carries a disease for man (histoplasmosis), as well as parasites that can infect other species.

House crow, *Corvus splendens*
This species was documented for Curaçao in 2002. It is a highly invasive species (Nyari *et al.* 2006) but strongly associated with man and man-disturbed habitats. One specimen was shot and the other did not survive. It was observed to be constantly harassed by the native West Indian mockingbird, *Mimus gilvus* (AOD, pers. obs.).

Black-rumped waxbill, *Estrilda troglodytes*
This bird had established extensive colonies in the Groot St. Joris (Chinchó) area in Curaçao, where they built many nests in an area with reeds along a stream. The species was wiped out during the 1977-78 period of drought (pers. comm. Joost Pronk). It is yet another example of an introduced species that had established a foothold but was subsequently eliminated during a period of extended drought. It is native to Central Africa. This species has established itself in Puerto Rico and Guadeloupe (1975), it has also been introduced on Martinique, where it is presumably uncommon and there have also been records from St. Thomas (Raffaele *et al.* 1998). The Orange-cheeked waxbill (*Estrilda melpoda*) has been

introduced in Puerto Rico, where it is present since early colonial times; there are also records of this species from Guadeloupe and Martinique (Raffaele *et al*. 1998). This species is native to West Africa. These *Estrilda* species are commonly kept cage birds, if they were to establish themselves on Aruba, Curaçao or Bonaire this would probably be only temporarily since they would probably be eliminated during extended dry periods. However they could probably establish a permanent presence in areas such as Bubali in Aruba, where a fairly large permanent pond with many reeds exists. Whether they could establish themselves permanently on one or more of the Dutch Windward Islands would be a fair guess.

Green-rumped parrotlet (*Forpes passerinus*)
In Curaçao these existed up to recently (Voous 1983) (Prins *et al.* 2009). These however did not survive and were probably eliminated during periods of prolonged drought.

Jungle fowl, *Gallus gallus*
The common chicken, or jungle fowl can have profound impacts on the flora and fauna of islands (Engbring 1983). The jungle fowl will prey on seeds, seedlings, endemic invertebrates and small reptiles. This species is currently especially problematic at the bottom of the Quill in St. Eustatius. Eradication is fully feasible and should be able to be accomplished easily by shooting and trapping.

Troupial, *Icterus icterus*
The Troupial was introduced in Bonaire by J.E. Joubert. According to Voous (1983), this happened in 1973, but probably took place somewhat earlier (GvB). J. E. Joubert was an uncle of GvB who remembers him catching troupials at Klein Piscadera plantation in Curaçao, in order to take these to Bonaire. These were released at Sta. Barbara plantation in Bonaire. This must have been around 1966. It could well be that there were later introductions also when around 1973 Joubert moved to Nikiboko (Bonaire). The introduction of the troupial must have had an effect on other birds, most likely on the Yellow oriole *Icterus nigrogularis*, but there have been no studies to document this.

Shiny cowbird, *Moluthrus bonariensis*
The shiny cowbird (*Molothrus bonairensis*) was first found in the wild in Curaçao in 1991 (Debrot and Prins 1992). It is now also found in Aruba where it is a recently established breeding resident since 1997. Bonaire it has been a casual visitor in the past, but there are no recent records (Prins *et al.* 2009). It is related to the troupials. This bird lays its eggs in the nests of other birds, just like a cuckoo. It especially likes the nests of trupials. In Martinique this bird is an important threat to the endemic Martinique troupial (*Icterus bonana*) and in Puerto Rico it has contributed significantly to the decline of the Yellow-Shouldered Blackbird (*Agelaius xanthomus*). In Curaçao the Shiny cowbird has been present since the early 1990's; the population could be derived from escaped cage birds, but it is not impossible that the animal arrived on its own. It must certainly have a detrimental effect on some of the local bird species. However, there are no studies that document its impact on these islands.

Sparrow (*Passer domesticus*)
The sparrow originates in Eurasia and Africa. The sparrow (*Passer domesticus*) was introduced from Holland to Curaçao in 1953 by Mr. Johan Jonckhout. For years they were only seen in the Mundo Nobo area where they were introduced. The founder population existed of only 8 birds. After a long period of genetic adaptation they spread out over the whole island and also made it to Klein Curaçao. They also reached Bonaire, travelling on a ship that had transported rice from the Antillean Rice Mills in Bonaire to Curaçao. Some rice spilled on the deck of the ship and on the return trip to Bonaire sparrows hitched a ride. In Bonaire they then spread very rapidly, indicating that they were probably already genetically adapted to their new climatic conditions, also the founder population may have been larger. In Aruba sparrows are also present, it is not known how they arrived and they might have arrived on their own from the Venezuelan mainland. The sparrow has also been introduced in St Maarten, Saba and St.

Eustatius. MacGregor-Fors *et al.* (2010) have shown what negative impact this species can have on Neotropical bird faunas.

Village weaver (*Ploceus cucullatus*)
This species was established on Curaçao from escaped cage birds in the early 1980 (Prins *et al.* 2009). It survives in a small area in Damacor, Curaçao,and could likely be eradicated with little effort (AOD, pers. obs.).

Baya weaver (*Ploceus philippinus*)
As with the village weaver, numbers are still limited on Curaçao (Prins *et al.* 2009), making eradication fully feasible.

Rose-ringed parakeets, *Psittacula krameri*
In Curaçao these existed up to recently (Voous 1983, Prins *et al.* 2009). For many years a feral group existed that used to nest in the San Rafael area. These however did not survive, they were captured and were probably finally eliminated during periods of prolonged drought.

Caribbean grackle, *Quiscalus lugubris*
This species was introduced from Venezuela in 1981 (Prins *et al.* 2009) and has established populations on the three ABC islands. Prospects for eradication seem good since, with exception for Aruba, the population sizes are still small. It is also common and established on St. Maarten (R. Hensen, pers. comm.).

Great-tailed grackle, *Quiscalus mexicanus*
This species appeared in Curaçao in the early 1990s (Prins *et al.* 2009) and has established a small breeding population. Prospects for eradication seem good.

Saffron finch, *Sicalis flaveola*
The saffron finch (*Sicalis flaveola*) was first seen in the wild in Curaçao in the late 1960's, again the population is almost certainly derived from escaped cage birds. Both the sparrow and the saffron finch tend to be more common in the inhabited areas, but are sometimes also seen in the bush (locally called mondi). It is not known what effects their introduction had on local birds, but the Rufous-colored sparrow *Zonotrichia capensis*, seems much less common in the inhabited areas than in the past. The species may have disappeared on Aruba (Prins *et al.* 2009) but is clearly well-established and on Bonaire, but still not abundant or wide-spread (F. Simal, pers. comm.).

Eurasian collared dove, *Streptopelia decaocto*
The Eurasian collared dove has been introduced in St. Maarten, Saba and St. Eustatius.
It originates in Asia and Eastern Europe. It was introduced to New Providence in the Bahamas in 1974 and to Guadeloupe in 1976. It has since been spreading through the Caribbean (Raffaele *et al*. 1998).

3.3 Reptiles

Panther anole, *Anolis bimaculatus*
Powell *et al.* (1992) document a reproductive population of *Anolis bimaculatus* for St. Maarten, likely introduced to the island from neighboring St. Eustatius. Subsequent work has failed to find the species back and it is surmised that they failed to establish and spread on the island.

Puerto Rican crested anole, *Anolis cristellatus*

This species was introduced from the Puerto Rico bank islands and has established a small population in St. Maarten. Ecological impacts or threats remain unknown (Powell *et al.* 2005).

Curaçao anole, *Anolis liniatus*

This species, endemic to Curaçao, was quite common in the 80's and 90's around Hotel Bonaire, Bonaire (R. Hensen, pers. comm.). Its current status remains unknown, and it seems that it may have died out on Bonaire. However, this would deserve more extensive verification.

Cuban green anole, *Anolis porcatus*

The Cuban green anole has established itself in the garden of the Radisson hotel in Aruba (first found Aug 2008), where it came in with plants imported from Cuba for landscaping (Odum and van Buurt 2009).

Cuban brown anole, *Anolis sagrei*

The species has also been found in the garden of the Radisson hotel in Aruba (found Aug 2008), where it came in with plants imported from Cuba for landscaping (see picture in: Fläschendräger and Wijffels 2009). They were present in lower numbers than *Anolis porcatus*. It is not known whether they are still present. Some *Anolis sagrei* were also present in St. Maarten, near Philipsburg Harbor. They were observed in March 2010 (Fläschendräger 2010).

Boa, *Boa constrictor*

Boa constrictor is now a serious pest on Aruba. The first boa was reported from Aruba in April 1999. In 1999 25 cases of boas found were reported to the Parque Nacional Arikok, by the end of December 2003, 273 *Boa constrictor* had been captured and by June 2008 1670 boas had been removed. *Boa constrictor* is now fully established and can be found all over Aruba. Of course such a new predator must have a substantial impact on the Aruban fauna. A study indicated that birds comprised 40.4%, lizards 34.6% and mammals 25.0 % of prey items which were identified (Quick *et al*. 2005). Most of the mammals were black rats. The boa is, for example, surely a threat to vulnerable populations of the Aruba subspecies of the Brown-eared conure *Aratinga pertinax arubensis.* This conure constituted 3.9 % of its prey. It is also likely that the boa will have a negative impact on the vulnerable Vesper mouse (*Calomys hummelincki*). The fact that *Boa constrictor* has managed to establish itself successfully on the most arid island in the Dutch Caribbean indicates that if introduced it could surely survive and thrive on the other islands as well. Barring the development of new methods it will be next to impossible to eradicate the boa on Aruba, at most some form of population control could be achieved at a fairly high cost. The Boa is most likely to be introduced via the pet trade; this is most likely how it came to Aruba, although this has not been proved. The import of boas on the other islands of the Dutch Caribbean should be totally prohibited. Those already on the islands should be registered and a permit should be required. It might be even better to completely prohibit the possession of such animals, however when instituting such a prohibition one runs the risk that persons who keep such animals will simply release them, since they would be very reluctant to kill an animal that they have been keeping as a pet and taking care of, often for a long time. One of the problems of the pet trade is that unless the owners are able to transfer ownership to someone else, they will simply release animals which for some reason they cannot handle anymore.

The Boa study on Aruba concluded that there is sufficient food for the boas when they are small, however when they get larger at a total length of about 1 meter, they need larger prey. Most cannot obtain enough food and some almost starve, the females reabsorb their eggs and produce less and smaller litter. Mortality is very high, yet still the boa managed to thrive and spread out all over the island. During periods of extended drought, their population would probably be severely reduced. The

last such period was in 2001-2003. Only near the waste dump where there are many rats were large healthy boas found. From this it is concluded that a larger snake such as a python might probably have a hard time establishing itself on Aruba. However this may not be true for some of the other less arid islands.

Rainbow whiptail lizard, *Cnemidophorus arenivagus*

This lizard was introduced in Aruba around 1950 and was formerly known as *Cnemidophorus lemniscatus lemniscatus* (van Buurt 2011). It was first discovered near the oil jetties in San Nicolas. In the 1990's it was found in areas where the soil is somewhat sandy; around San Nicolaas, Cura Cabai, Mabon, Brasil, at the location of the old airfield "de Vuist" and on and around the Aruba Golfclub. Nowadays its range seems to have extended somewhat, in 2008 GvB saw it at Vader Piet and it was reported near Guadirikiri (both Aruba locations). In 2010 Facundo Franken saw several at Santu Largu, Savaneta (pers. comm.). On the other hand houses have been built in the "de Vuist area" and in this area it seems to have disappeared. This species does not displace *Cnemidophorus arubensis*, it can only establish a precarious foothold against *C. arubensis* in those areas where the soil is sandy.

Yellow-headed gecko, *Gonatodes albogularis*

This gecko is more widely distributed in the Caribbean and was documented on Aruba and Curaçao (Wagenaar Hummelink 1940) but has not been recorded on Aruba since and on Curaçao only once (van Buurt 2011, 2005). It has probably not survived.

Antilles gecko, *Gonatodes antillensis*

This species has been recorded for Aruba (Wagenaar Hummelink 1940) and was likely introduced from Curaçao by man. It has apparently not been able to maintain its population (van Buurt 2001, 2005, Powell *et al.* 2005).

White-banded gecko, *Gonatodes vittatus*

This species appears to have been introduced from Venezuela to Aruba and Curaçao (Wagenaar Hummelinck 1940). In Aruba it is widely distributed whereas in Curaçao the species has only been documented from a small area many years ago (van Buurt 2001, 2005, Powell *et al.* 2005).

Underwood's spectacled tegu, *Gymnopthalmus underwoodi*

This species is of South American origin and has been introduced to St. Maarten where a small and limited population persists (Powell *et al.* 2005).

Cosmopolitan house gecko, *Hemidactylus mabouia*

The cosmopolitan House gecko (*Hemidactylus mabouia*), which was probably introduced in the 1980's in Curaçao (Wijngaarden van, 1988) is now found on all three islands. In 1999 van Buurt found it in Bonaire (van Buurt 2005). It was first reported from Aruba by Lundberg (2003), who found it in January 2002. In Curaçao it has mostly displaced the endemic gecko *Phyllodactylus martini* in houses but is not found in the wild. The same will probably happen in Bonaire. It is not known how it affects *Phyllodactylus julieni* in Aruba. In the Windward Islands the Cosmopolitan house gecko has been present much longer. It is said that *Hemidactylus mabouia* has been introduced in the New World from Africa and that it came in with slave ships. For this reason, in the West Indies, this gecko is sometimes called "Wood slave" or "African wood slave". In Brazil it is also said that this gecko was introduced with the slave trade (Vanzolini, 1968). Kluge (1969) thinks this gecko arrived in the West-Indies from Africa by natural means. It may be that older populations that arrived naturally were later replenished with newly introduced arrivals. Up to now the related gecko *Hemidactylus haitianus* which is found in Haiti was considered to be a West-Indian endemic which would have arrived from Africa by natural means, but

apparently it is almost identical to the African *Hemidactylus angulatus* and this indicates it could have arrived in historical times as an introduction by man, (Powell *et al*. 2011).

Green Iguana, *Iguana iguana*

This species is native to the Leeward Dutch islands and Saba. The Saba race is considered an endemic melanistic variety. However, in general, the species is invading the Lesser Antilles from the mainland of South America and replacing the Lesser Antillean green Iguana, *Iguana delicatissima*. The species was introduced on St. Maarten from Curaçao, where it has displaced *Iguana delicatissima* (Powell *et al.* 2005). If it were introduced on St. Eustatius where *Iguana delicatissima* lives, the same result is to be expected. The species also interbreeds with *I. delicatissima*, which makes the latter vulnerable to loss by hybridization. *I. delicatissima* is a highly endangered species which is also an international conservation priority for St. Eustatius and accidental introduction of the Green Iguana could be disastrous..

Corn Snake, *Pantherophis guttata*

The Corn snake (*Pantherophis guttata* formerly *Elaphe guttata*) came in on Curaçao (Perry *et al*. 2003) but has been extirpated successfully (van Buurt 2005). This snake might have been able to establish itself. It may have come in with imported plants but could also have been brought in by the pet trade. This species is commonly kept as a pet and had been for sale in Curaçao. It could be a serious threat to the endemic Curaçao three-scaled groundsnake snake *Liophis triscalis*. If it could almost establish itself in Curaçao, it may very well have the capability to establish itself in Aruba and Bonaire as well. The Corn snake has established itself on St. Maarten (Powell *et al.* 2005) and could certainly establish itself on Saba and/or St. Eustatius. The Corn snake is indigenous to North America and is found in temperate regions. It also occurs naturally in Florida which is subtropical. Nevertheless it is strange that such a snake apparently has managed to adapt itself to full tropical conditions. Often reptiles from temperate regions need a cool period to reproduce. This example illustrates how difficult it sometimes is to foresee whether an introduced species will be problematic in a new environment or not.

Flowerpot blind snake, *Ramphotyphlops braminus*

This species originates from Africa and Asia and has been widely introduced in tropical and subtropical areas of the world (Wallach. 2008). It is a predator on termites and ants, and could possibly establish itself in the wild, using domestic gardens as a stepping-stone. It is a species that could compete with and replace the native blind snake. However it is doubtful whether it can survive in the arid areas outside of gardens. It has been found and killed in ornamental gardens several times in Curaçao.

Common slider, *Trachemys scripta*

This turtle species is recorded as established in semi-natural freshwater on St. Maarten (Esteban 2009) where it is widespread, and on Aruba where it is limited to few sites (Powell *et al.* 2005). Because it is limited to freshwater, it has little potential to expand into other habitats. However, its impact on native freshwater fauna in St. Maarten and Aruba is unknown. Powell *et al.* (2005) believe the species has little effect. It cannot survive in semi-permanent waters when they dry out and for this reason it is likely that it has little impact on the islands endemic seasonal freshwater species. It is fairly agreed that the natural freshwater habitats of St. Maarten have been lost due to deforestation by man and livestock. Destruction of freshwater habitat on St. Maarten has for instance led to the eradication of the disease schistosomiasis for which the snail *Biomphalaria glabrata* is the intermediate host. Prior to the 1930s this disease was common in St. Maarten but is no longer a problem (Prentice 1980).

3.4 Amphibians

Johnstone's frog, *Eleutherodactylus johnstonei*

The whistling frog originates in the Windward Islands, probably in St Kitts (Powell *et al.* 2005). It put its egg in clumps which are attached to the roots and stems of plants. It thus spreads with the trade in ornamental plants. It is present on most of the islands of the Lesser Antilles. The whistling frog has been introduced in Jamaica, Bermuda, Guyana, Trinidad and into the coastal regions of Venezuela and Colombia. It is now found in Aruba, Curaçao and Bonaire, where it came in with plants imported from Venezuela. In Curaçao they came in during the late 1970's or early 1980's, in Bonaire and in Aruba in the 1990's. In Aruba it is found in the garden of the La Cabaña Hotel. In the dry climate of Aruba, Curaçao and Bonaire they depend on gardens for their survival. In Saba, St. Eustatius and St. Maarten they spread widely into natural habitat.

The related species *E. coqui* from Puerto Rico has been introduced into Hawaii. In Hawaii the species is considered a potential threat to ecosystem processes and terrestrial invertebrates it preys upon (Beard *et al.* 2009). The most serious impact has been economic damage in the way of lower house prices. Cost to control the species by public agencies was more than 4 million dollars in 2007. Costs to landowners and businesses was not included. The loud and penetrating mating calls disrupt peace and quiet and form a major nuisance which lowers the value of property where the species is present. *E. johnstonei* is a similar nuisance species in the Dutch Caribbean. In Hawaii, citric acid is successfully used to eradicate and control *Eleutherodactylus* (Beard *et al.* 2009).

Martinique robber frog, *Eleutherodactylus martinicensis*

This species occurs naturally in the Lesser Antilles but has been introduced to St. Maarten either via the nursery trade or as a stow away in cargo (Powell *et al.* 2005).

Cuban tree frog, *Osteopilus septentrionalis*

This species is now established on Bonaire (2004), Curaçao (2006), (van Buurt 2005, 2007) and St Maarten (Powell *et al.* 2005). The Cuban tree frog originates in Cuba, the Cayman Islands and the Bahamas. It is a "tramp" species which can survive travel in ships and containers. It has been introduced in Florida, Hawaii, several islands of the BVI, in the USVI, Puerto Rico, Anguilla, and St. Martin (Powell 2005) and is now also found on Bonaire (2004) and Curaçao (2006). These frogs are very voracious, they climb very well. It is widely distributed on St. Martin (Powell et al 2005). They eat insects and spiders and compete for food with anoles and geckos, will eat other frogs, geckoes and small anoles and even small bird nestlings. They soil the water in cisterns. Often they are introduced with imported plants or building materials. Because of the very dry climate in Aruba, Curaçao and Bonaire, they will probably not be able to penetrate into the bush, or may be only temporarily during wet years, and will probably form less of a problem than in other Caribbean islands. If introduced in Aruba this will not be a major threat, but certainly an unwanted nuisance. In Saba and/or St Eustatius this frog could cause more serious problems, since they would survive in nature. On these islands people also still depend on water from cisterns in which it can easily breed. Roberto Hensen (pers. comm.) has seen the species once on St. Eustatius but it is possibly not yet established.

Froth-nest frog, *Pleurodema brachyops*

The froth-nest frog was introduced in Curaçao in 1910 from Aruba and in Bonaire in 1928 from Curaçao (Wagenaar-Hummelinck 1940). In Aruba it is probably a native species but the possibility that it may have been introduced by the Caquetío Indians from the mainland cannot be fully excluded (van Buurt 2005). This animal can be considered to be an enrichment of the local fauna. However, it is a voracious freshwater predator and may have affected the original freshwater fauna in unknown ways. Today it is appreciated by man especially as it consumes mosquito larvae in stagnant water pools.

Cane Toad, Marine toad, *Rhinella marinus*

The cane toad (*Rhinella marinus* formerly *Bufo marinus*) has been introduced in Aruba where it is now a pest; many cats and dogs are poisoned trying to eat them. The Cane toad could certainly survive in Curaçao and Bonaire and should be kept out. It has been widely introduced for biocontrol but has not fulfilled that role and has itself turned into a pest. It is now widely distributed in the Caribbean (Powell *et al.* 2005).

3.5 Fishes

Guppy, *Poecilia reticulata*

This species is a native species for South America but has been widely introduced elsewhere for mosquito control. It has been present for more than half a century on Curaçao but is a relatively recent exotic in local fresh waters (Debrot 2003), which has established itself in Bonaire and Aruba as well (Hulsman *et al.* 2008). It is present year-round in semi-natural and man-made fresh waters, which probably reseed natural systems during the rainy seasons.

Green swordtail, *Xiphophorus helleri*

This species is native to Central America but has greatly expanded its range, probably due to its use as an aquarium species. For instance, this hardy, omnivorous live-bearing species is firmly established in the wild in Florida. Hulsman *et al.* (2008) document it from one fresh/brackish water site on Aruba and indicate that the specimen was from aquarium sources. Even though natural spreading in freshwater on Aruba would seem difficult due to the scarcity of such habitat, the species is one to watch and at the present time could easily be extirpated.

Two other important species should at least be mentioned here. These are the Mozambique tilapia, *Oreochromis mossambica*, which has established itself in freshwaters of the Leeward Dutch Caribbean and the Machuri, *Poecilia vandepolli*, native to the Leeward Dutch Caribbean but introduced and established on St. Martin. These species certainly must affect seasonal freshwater systems but are euryhaline and are able to persist and spread because of their tolerance to salinity. For this reason they are not discussed here, but are treated more fully in a separate report on the marine exotic species of the Dutch Caribbean (Debrot *et al.* 2011).

3.6 Insects

Vagrant emperor dragonfly, *Anax ephippiger*

The Vagrant emperor dragonfly is known to make mass migrations in southern Europe and Africa. The species has been documented from Guadeloupe, Dominica and Surinam and has probably recently invaded and established itself in the West Indies from Africa (D. Paulson, pers. comm.). It was collected in Curaçao in 2011 (by C. de Haseth).

Honey bee, *Apis mellifera*

The honey bee was introduced in Curaçao in the early 20th century, probably around 1905; these were probably Italian bees (*Apis mellifera ligustica*). Around 1920 bees were introduced to Curaçao from Haiti by JJAH Joubert. In St Eustatius the honeybee was introduced in 1903. According to Bitter (1950) the first honeybees in Aruba were introduced in 1938, these bees came from Holland, but their introduction was not succesfull. The bees were extraordinally aggressive and the harvest of honey was very low. This makes one wonder whether these bees could have been infected with *Varroa* mites. According to others (Ruben Croes, pers. communication) the first bees were introduced in Aruba in the 1920's. In Curaçao the indigenous stingless bees of the genus *Melipona* are still found but are not very common. There are

also Carpenter bees of the genus *Xylocopa*. One would surmise that the introduction of *Apis mellifera* must have influenced the numbers of such native species. Today honey bees compete with or even kill active nests of cavity-nesting endangered parrots on Bonaire (Williams 2009).

Oldroyd *et al*. (1994) for instance found a 50% overlap in nest site selection between honey bees and an Australian parrot species. In Curaçao the honey bee are responsible for human and household pet deaths in Curaçao almost every year. A review by Moritz and Hartel (2005) concluded that while the honey bee is an important invasive species and can affect survival and fecundity of native bees, its effect on biodiversity remains limited. The study does concede that appropriate baseline data is lacking because bees were extensively introduced well before entomology was sufficiently developed to have established baseline studies of native bee faunas. The review also fails to address honey bee introductions in islands, possibly because of lack of data.

The Mimic butterfly*, Hypolimnas missipus*
This butterfly originates in the Old World and was probably blown over "naturally" from Africa. It is now firmly established in the Caribbean and is known from all three of the ABC islands (Debrot *et al.* 1999, Miller *et al.* 2003). It is present only in limited numbers and likely has little negative impact on flora or fauna.

3.7 Molluscs

West-Indian *Bulimulus*
An introduced species found in Curaçao (2010), is the West-Indian Bulimulus, *Bulimulus guadaloupensis* (identification B. Breure, Leiden, The Netherlands). It was introduced in Curaçao in 1974 from Saba (Breure 1975), it is now widespread in many gardens on Curaçao but seems to be unable to survive outside of gardens. It seems to be very susceptible to predation by *Cnemidophorus* lizards. (GvBuurt, pers. observation). The species originates in the Windward Lesser Antilles (including St. Maarten, Saba and St Eustatius) where it is native (Coomans 1967, Breure 1974). Furthermore, it has been introduced in Jamaica, Florida and very likely also in Hispaniola (Breure 1974)

Helisoma duryi intercalare
This freshwater snail is a carrier of the disease of schistosomiasis elsewhere and was imported from Venezuela (Kuyp 1949). Because freshwater is limited this exotic species can probably not become overly abundant and does not pose an immediate health risk to man.

Other important invasive mollusk species such as the Giant East African land snail, *Achatina fulica,* and the Cuban garden snail, *Zachrysia provisoria*, are also present in the Dutch Caribbean but are not discussed here as they are treated separately elsewhere along with other typically agricultural plant diseases and pests.

3.8 Earthworms (Oligochaeta, Phylum Annelida)

Earthworms have a critical function in soils ecosystems (Hendrix and Bohlen 2002). At least 28 exotic earthworms are present in the Caribbean. Of these at least eight species have been documented for the islands of the Dutch Caribbean (Fragoso and Brown 2007). According to Gonzalez *et al.* (2006), over 50% of Caribbean exotic earthworms were originally from Europe and Asia, 18% were from South America, and 16% were from West Africa. Most of them belong to the families Megascolecidae and Lumbricidae and are widely distributed in natural ecosystems, pastures and croplands (Gonzalez *et al.* 2006). In contrast, most native species in the Caribbean Islands mostly belong to the families

Octochaetidae (65%) and Glossoscolecidae (Rodrıguez *et al.* 2006). In general, endemic species are often restricted to a single island (Fragoso et al. 1999). Invasive species often lack natural checks on population growth and form a significant threat to native and /or endemic fauna.

At present, traffic in ornamental plants to the Dutch Caribbean remains intensive, which means that associated introduction of invasive earthworms also likely continues to be intensive. Very little is known about this phenomenon and even less about its consequences. Nevertheless, the Dutch Caribbean also has a native and endemic earthworm fauna (Fragoso and Brown 2007), but little recent information is available known about its current status and potential threats.

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4 Discussion

In this review we exclude all invasive animals that are principally agricultural pests and or animal and plant diseases, which are treated separately elsewhere. Even so, we document 12 exotic mammals, 16 birds, 18 reptiles and amphibians, 2 freshwater fishes, 3 insects, 2 mollusks and 8 exotic earthworms for one or more of the islands of the Dutch Caribbean. This amounts to a total of 61 exotic animal species presently living in the wild or semi-wild state on one or more of the Dutch Caribbean islands.

We also discuss 11 species which at one time were recorded but have since disappeared. These include among others the feral horse, five bird species and two lizard species. A number of species have the status of being native in parts of the Dutch Caribbean but introduced to other parts where they are not native. These species amount to one bird, two reptiles, one amphibian, one fish and one land snail. The most threatening of this last category is the green iguana, as introduced to St. Maarten where it outcompetes and hybridizes with the weaker Lesser Antillean iguana.

With so many species to consider, and funding generally limited, priorities need to be set. We propose two main criteria to be used for setting priorities, namely the “degree of risk or impact” and the “degree to which eradication is feasible” (Fig. 1). The use of such criteria seem useful to help decide which species to act on and to what degree (and cost) to take action. Such criteria can be applied to individual species but also to species groups.

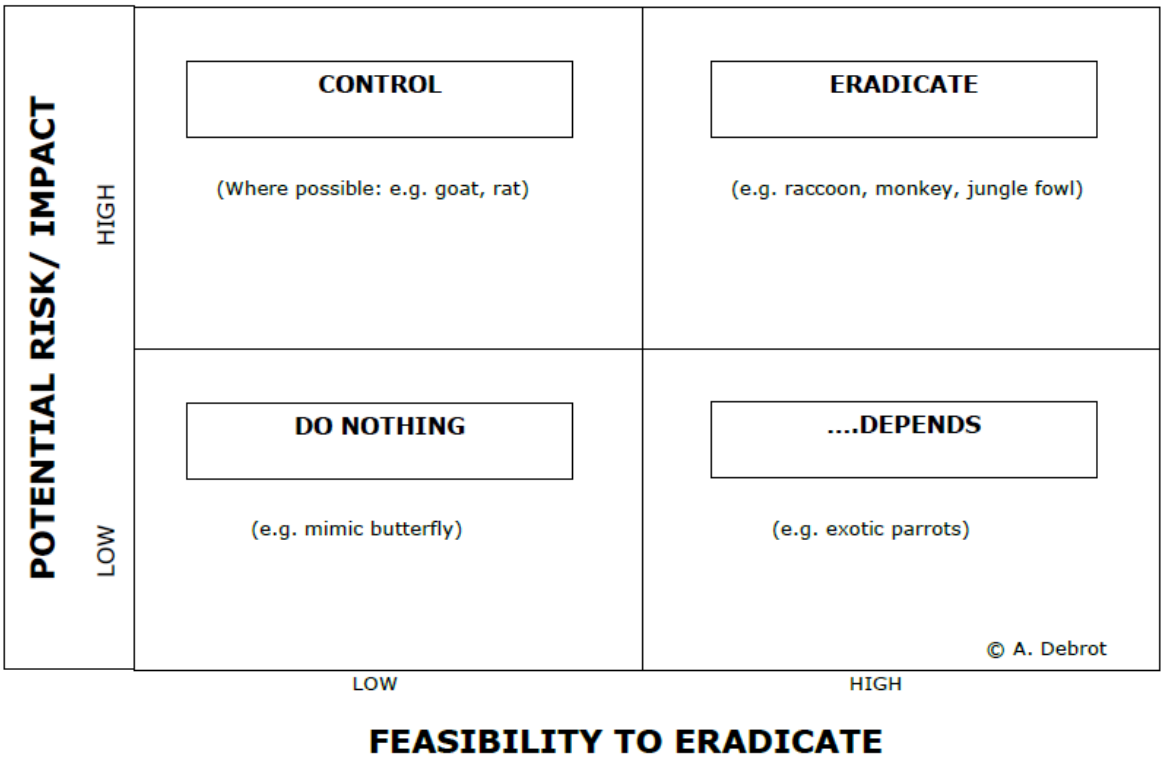

Figure 2. Invasive species “action quadrant”, as an aid to decision making for control and eradication.

Not only at species level but also at the species group level there are important contrasts between the various taxonomic groups. An example is the contrast between for instance mammals (high impact) and psittacid birds (parrots) (low impact).

Mammals are the most successful and advanced evolutionary terrestrial animals group. They are vigorously active, highly adaptable endotherm animals that require a lot of food and greatly impact the ecosystems in which they live. Therefore it is not surprising that our review shows that some of the most deleterious animal introductions have been the mammals, particularly the grazers and the predators. Among these, the four key species are grazing goats, the mongoose, the cat and the black rat. In most cases, such species cannot be eradicated because they are widespread and firmly established, or being widely kept as livestock or pets, but must be controlled in sensitive areas where possible (Fig. 2). However, our review also shows that many introduced mammals are still present in relatively small populations, making eradication still feasible (eg. raccoon).

Several large parrots (psittacids) have become feral in Curaçao based on escaped cage birds. These animals today remain strongly dependent on gardens for their continued survival and so far have not truly established themselves in the wild. This does not mean that this is not possible, as on Bonaire (and formerly on Curaçao and Aruba) large psittacids are a natural part of the native avifauna. It is also must be kept in mind that aridification by man and loss of former moist tropical forest (Debrot *et al.* 1999) has certainly had a negative impact on the current vegetation's natural capacity to support not only forest butterflies, but also large psittacids. For now, exotic parrots would seem to have limited potential to impact other species and ecosystems. History has further shown that large parrots are relatively easy to eradicate (slow reproduction, high market value and easy targets). Therefore, urgency to take action against large parrots at present is generally low (eg. Fig. 2).

4.1 Pathways of introduction

Various main pathways of introduction can be identified for the species discussed here and some generalizations would seem at hand. For instance, most mammals have been introduced for their husbandry potential. In contrast most birds have been introduced as pet species. With exception of one species, *Pontodrilus litoralis*, (Blakemore 2007) importation of most of the documented earthworms probably took place within soil that came in with seedlings of exotic fruit trees, whereas today the main risk for new exotic earthworms certainly lies with the massive importation of exotic plants. Nevertheless, today there are three main pathways involved with the introduction of IAS that are not principally agricultural pest species. These are a) containerized cargo transport, b) international trade in ornamental plants, c) international pet trade.

a) Containerized cargo transport: Nowadays transport is much faster than in the past and many organisms that hitchhike on cargo have a much greater chance to survive the journey; the fact that cargo is nowadays containerized is also an important factor. The standardized freight container was one of the most important innovations of the 20th Century. Containerized cargoes travel from their point of origin to their destination by ship, road and rail as part of a single journey, without unpacking. This simple concept is the key element in cheap, rapid transport by land and sea, and has led to a phenomenal growth in global trade. Likewise, containerized air cargo has led to a remarkable increase in the inter-continental transportation of goods, particularly perishable items such as flowers, fresh vegetables and live animals. In both cases, containerization offers great advantages in speed and security, but reduces the opportunity to inspect cargoes in transit. An inevitable consequence is the globalization of undesirable species of animals, plants and pathogens. Moreover, cheap passenger flights offer worldwide travel for viral and parasitic pathogens in infected humans. The continued emergence of exotic pests, vectors and pathogens throughout the world is an unavoidable consequence of these advances in transportation technology (Reiter, 2010).

c) International trade in nursery plants: There is also a large international trade in nursery plants, including trees and sometimes large palms for landscaping. Nowadays on many Caribbean islands trees and large palms are imported for the landscaping of hotels or other tourist projects. Such large palms and trees are transported in open-top containers.

b) International pet trade: Then there is a large pet trade which also deals in exotic animals, which did not exist to this extent in the past. Dogs and other house pets now travel all over the world with their owners, usually there are adequate veterinary rules, but in some cases epizootics like ticks and the diseases they may carry, can still come in.

5 Conclusions and Recommendations

From our overview we conclude that the key priorities for successful action against aggressive exotic animals are:

- control of goats;
- control of introduced predators (rats and cats) near seabird breeding colonies;
- eradication of several small populations of exotic mammal predators and reptiles as long as this is possible before the get a strong foothold and spread;
- eradication of introduced species from small offshore islands which serve (or served) as seabird breeding habitat.

In addition to such on-island action against species already present, it is critical to prevent further introductions. Two key action points are urgently needed: a) develop the existing legislation and b) establish biosecurity units empowered for action.

Existing legislation

The existing legal framework to prevent the introduction of invasive species and pests and plant diseases and to combat them once they have been introduced is critically insufficient. Saba has an Island ordinance which prohibits the introduction of “exotic species” without permission of the Saba island government. Both in the Netherlands Antilles and Aruba a phytosanitary certificate is required to import plants or hay. However these measures have clearly been insufficient. A major problem is that there are no phytosanitary laws which enables the government to confiscate and destroy imported plants which turn out to be infected. Even if they are clearly infected, if accompanied by a valid phytosanitary certificate they cannot be legally impounded. There are further no quarantine regulations for plants, nor is it possible to prohibit the import of plants or certain species of plants from countries where certain plagues are known to exist. Such legislation does exist for veterinary products which could transmit diseases which can affect human beings or animals. Adequate phytosanitary laws and laws to strengthen defenses against invasive species are urgently needed. Draft legislation exists, but has not been enacted.

Invasive Species Management Teams (ISMTs)

ISMTs have to be established on each island to assist the customs in identifying and keeping out unwanted species. In this, the team will provide extension services on plant diseases and invasive species and should regularly organize presentations to customs, pest control, landscaping and garden maintenance companies, nature groups and the general public. It is very important to establish and maintain such contacts, as public involvement and feed-back is key to detecting new problems rapidly. Another key task of biosecurity units is to act as a rapid response unit, combating invasive species, pests and plant diseases that came in and trying to extirpate them before they manage to establish a permanent foothold. There is a potential role for the “Team Invasieve Exoten” of the Ministry of Economic Affairs, Agriculture and Innovation.

The ISMT should also develop, regularly update and reevaluate a list of “Alert species”, and should establish contingency plans to combat the plant diseases and invasive alien species on this listing. The ISMT will maintain close contacts with all Kingdom island partners and stakeholders, regional organizations such as FAO, CABI and USDA/Aphis and with local commercial pest control companies and also with local and regional companies supplying chemicals to combat species (insecticides, acaricides, fungicides, herbicides, mollucides etc.). Furthermore, the ISMT should also establish a list of exotic animal species, of which the import is prohibited, such as: Monitor lizards, desert hedgehogs, Corn snakes and other snake species which could survive in the wild. So far only Curaçao and Aruba have long

had plans to develop a biosecurity unit, which have not yet been realized. Clearly, such a unit is needed for the Caribbean Netherlands.

Policy Frameworks

Finally, initiatives to develop such legislation and ISMTs needs to take place and be firmly imbedded in policy frameworks. The first step ahead in these respects should be to outline an **Invasive Species Strategy and Action Plan** (ISSAP). For this, establishing clear goals is essential. Policy action goals can namely be distinguished at both primary (framework) and secondary (implementation) levels (Townsend 2009).

At the primary level, key goals would for instance be to:

- lay down IAS policy;
- develop and amend legislation to deal with IAS;
- develop and equip an ISMT that functions based on an inter-insular coordination mechanism which allows them to act decisively and swiftly.

Key secondary goals would be to:

- develop an IAS information system and database;
- prepare a strategic management plan based on a sequential approach of prevention, eradication, control and restoration;
- conduct capacity trainings for institutions involved in the identification control and handling of IAS;
- implement programs together with customs to prevent introduction and establishment of IAS;
- implement program for eradication and control of priority IAS species present, together with nature managers;
- facilitate research into IAS;
- establish periodic IAS monitoring.

Jointly developing an ISSAP falls beyond the scope of this project but is recommended as the key step forward in dealing with IAS. However, lack of an ISSAP should in no way be seen as a hindrance to parties to taking directed critical action at the local level (eg. goats in the national parks and cats at seabird breeding sites).

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Quality assurance

IMARES utilises an ISO 9001:2008 certified quality management system (certificate number: 57846-2009-AQ-NLD-RvA). This certificate is valid until 15 December 2012. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V. Furthermore, the chemical laboratory of the Environmental Division has NEN-AND-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 27 March 2013 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation.

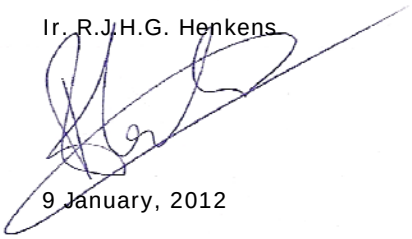
Justification

Report C001/12
Project Number: 4308202004

The scientific quality of this report has been peer reviewed by the a colleague scientist and the head of the department of IMARES.

Approved: Ir. R.J.H.G. Henkens

Signature:



Date: 9 January, 2012

Approved: F.C. Groenendijk, MSc.
Head of Department

Signature:

Date: 9 January, 2012

Appendix 1.

List of current invasive terrestrial and freshwater animal and disease species in Dutch Caribbean islands.

Definition: Invasive species are non-indigenous species (or exotic species) introduced by historic human actions, whose introduction causes, or is likely to cause, economic or environmental harm or harm to human health (US government definition). Green shading = current invasive species, Yellow shading = potential invasive species, Blue = native range, Red = eradicated.

Species	**common name**	**region of origin**	**date of introdution**	**mode of introduction**	**Aruba**	**Bonaire**	**Curacao**	**Saba**	**St Eustatius**	**St Maarten**	**Impacts ecological/ economical**	**Principal determinant for presence**	**Principal habitat affected**	**Prospects for control**	**Priority for research**	**Priority for**
Mammals																
Rodents																
Mus musculus	mouse	Old world	16th century	transport of goods							high	human habitation	widespread	low		low
Rattus norvegicus	brown rat	Old world	16th century	transport of goods							high	human habitation	lowlying coastal areas	low		low
Rattus rattus	black rat	Old world	16th century	transport of goods							high	human habitation	widespread	good, locally		high, locally
Household pets																
Canis familiaris	dog	Old world	16th century	pet							medium	human habitation	widespread	good, locally		high, locally
Felix domesticus	cat	Old world	16th century	pet							high		widespread	good, locally	*high*	high
Livestock																
Capra hircus	goat	Old world	16th century	agriculture							high	fresh water	widespread	good	*low*	high
Equus assinus	donkey	Old world	16th century	agriculture							high	fresh water	widespread	good	low	high
Equus equus	feral horse	Old world	16th century	agriculture												
Ovis aries	sheep	Old world	16th century	agriculture							high	fresh water		good		
Sus scrofa	pig	Old world	16th century	agriculture							growing	fresh water		good	low	high, locally
Others mammals																
Cebus sp.	capuchin monkey	S. America	late 1990s	pet												
Chlorocebus pygerythrus	vervet monkey	Africa	early colonial	pet							high			good		high
Civettictis civetta	African civet	Africa	1600s	agriculture												
Herpestes auropunctatus	mongoose	Africa	1888	agriculture							high		widespread	poor	*low*	low
Procyon lotor	raccoon	N. America		pet							high			good		high
Birds																
Amazona amazonica	Orange-winged parrot	S. America		exotic pet trade							low	human habitation	gardens	good		
Amazona autumnalis	Red-lored parrot	S. America	> 1977	exotic pet trade							low	human habitation	gardens	good		
Amazona ochrocephala	Yellow-crowned parrot	S. america		exotic pet trade							low	human habitation	gardens	good, locally		low
Ara severa	Chestnut-fronted ara	S. america		exotic pet trade							low	human habitation	gardens	good		
Aratinga acuticaudata	blue-crowned parakeet	Venezuela	>2007	exotic pet trade							low	human habitation		good		

Species	common name	region of origin	date of introdution	mode of introduction	Aruba	Bonaire	Curacao	Saba	St Eustatius	St Maarten	Impacts ecological/ economical	Principal determinant for presence	Principal habitat affected	Prospects for control	Priority for research	Priority for
Bubulcus ibis	cattle egret	Eurasia, Africa	1944	natural dispersal							*?*	disturbance	many	poor	low	low
Columba livia	rock dove	Old World		agriculture							?	human habitation	limestone cliffs	good, locally		good, locally
Corvus splendens	House crow	Asia	2002	transport of goods							none, eradicated	ocean going ships	anthropogenic landscapes		low	low
Estrilda troglodytes	red-eared waxbill	Africa		exotic pet trade							none, disappeared					
Forpus passerinus	Green-rumped parrot	N. South America	> 1940	exotic pet trade							none, disappeared					
Gallus gallus	Jungle fowl	Eurasia	16th century	agriculture							high		moist forest	good	low	high
Icterus icterus	troupial	Curacao	1973	pet							*?*		widespread	low	*low*	low
Molothrus bonariensis	shiny cowbird	S. America	1985	pet							high	human habitation	widespread	poor		low
Passer domesticus	house sparrow	Eurasia, Africa	1953	pet							*high*	human habitation	widespread	poor	high	low
Ploceus cucullatus	village weaver-bird	Africa	1980s	exotic pet trade							?	human habitation	suburban landscapes	good		
Ploceus philippinus	Baya weaver	S.E. Asia	1980s	exotic pet trade							?	human habitation	suburban landscapes	good		
Psittacula krameri	rose-ringed parakeet	Africa		exotic pet trade												
Quiscalus lugubris	Caribbean grackle	N. South America	1981	pet								human habitation	coastal mangroves	good		
Quiscalus mexicanus	Great-tailed grackle	N. South America	>1991	natural dispersal								human habitation	coastal mangroves	good	low	
Sicalis flaveola	saffron finch			pet									widespread	poor	low	low
Streptopelia decaocto	Eurasian dove	Old World	late 1970s	pet												
Reptiles																
Anolis bimaculatus	Panther anole	St. Eustatius		?												
Anolis cristellatus	Puerto Rican crested anole	Puerto Rico		ornamental plants												
Anolis liniatus	Curacao anole	Curacao	1980s?	?												
Anolis porcatus	Cuban green anole	Cuba	2008	ornamental plants							?			good		
Anolis sagrei	Cuban brown anole	Cuba	2008	ornamental plants							?			good		
Boa constrictor	Boa		1990s	pet							high			low		high, locally
Cnemidophorus arenivagus	Rainbow whiptailed lizard	Venezuela	1950s	?							?			good		
Gonatodes albogularis	Yellow-headed gecko	Caribbean														
Gonatodes antillensis	Antilles gecko	Curacao														
Gonatodes vittatus	White-banded gecko	S. America														
Gymnopthalmus underwoodi	Underwood's spectacled tegu	S. America														
Hemidactylus mabouia	Cosmopolitan House Gecko	Africa	1980s	?							?			low		
Iguana iguana	Green Iguana	S. America		?							high		all	low		
Pantherophis guttata	Corn snake			pet							high			low		
Ramphotyphlops braminus	Flowerpot blindsnake			ornamental plants							low			good		
Trachemys scripta	Common slider	N. America		exotic pet trade							?			good		

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Amphibians																
Eleutherodactylus johnstonei	Johnstone's frog	Leeward islands		ornamental plants							?	anthropogenic	anthropogenic	low		
Eleutherodactylus martinicensis	Martinique robber frog	Leeward islands		ornamental plants							?	anthropogenic	anthropogenic	low		
Osteopilus septentrionalis	Cuban tree frog	Cuba		ornamental plants							low	anthropogenic	anthropogenic	low		
Pleurodema brachyops	froth-nest frog	Aruba		transport of goods							low?	freshwater	aquatic	poor		
Rhinella marinus	Cane Toad, Marine toad	Colombia		pet							high	freshwater	aquatic	poor		?
Fish																
Poecilia vandepolli	Machuri	ABC islands		aquarium species							?	fresh water	fresh water	poor	low	low
Xiphophorus helleri	Green swordtail	Central America		aquarium species							?	fresh water	fresh water	good	low	high
Insects					**Aruba**	**Bonaire**	**Curacao**	**Saba**	**St Eustatius**	**St Maarten**						
Anax ephippiger	Vagrant emperor	Europe, Africa	2011	natural dispersal							?	fresh water	fresh water	low		low
Apis mellifera	Honey bee	Old World	early 1900s	agriculture							high		rock cliffs	good, locally		high, locally
Hipolymnas missipus	Mimic butterfly	Old World tropics	1996	natural dispersal							low			low		low
Mollusca																
Bulimulus guadalupensis	West-Indian Bulimulus	Saba	1974	pet							*?*			good		high
Helisoma duryi	freshwater snail	Venezuela	1940s	aquarium species							*low*			low		low
Earthworms																
Dichogaster affinis		W. Africa	Early colonial period	transport of agricultural goods							*?*			low		
Dichogaster bolaui		W. Africa	Early colonial period	transport of agricultural goods							*?*			low		
Dichogaster modighlianii		W. Africa	Early colonial period	transport of agricultural goods							*?*			low		
Dichogaster saliens		W. Africa	Early colonial period	transport of agricultural goods							*?*			low		
Eudrilus eugeniae		W. Africa	Early colonial period	transport of agricultural goods							*?*			low		
Polypheretima elongata		Asia	Early colonial period	transport of agricultural goods							*?*			low		
Pontoscolex corethrurus		S. America	Early colonial period	transport of agricultural goods							*?*			low		
Pontodrilus litoralis		India	Early colonial period	Sand-ballast/natural dispersal							*?*			low		